Estimating Mathematical Model for Additive Signal Dependent Noise in Captured Images under Low Lightness Conditions

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ABSTRACT

The main aspects that have been the focus into introduced the best mathematical models for signal dependent noise distribution in low lightness binary images(black and white targets), where have been captured several images in different lightness values from (0 Lux to 7 Lux). Then computed the probability distribution for the estimated additive noise separately in each image targets (black target and white target).After that using Table Curve Software to estimate the best matching eq. with noise distributions, where get high agreement Gaussian distribution function with the computed real noise distribution for both image target (black target and white target), and for two camera types.

Keywords: Additive Noise, Images Lightness, Distribution Probability, Table Curve.

1. INTRODUCTION

The amount of light coming to the eye from an object depends on the amount of light striking the surface, and on the proportion of light that is reflected. If a visual system only made a single measurement of luminance, acting as a photometer, then there would be no way to distinguish a white surface in dim light from a black surface in bright light. Yet humans can usually do so, and this skill is known as lightness constancy [1]. Most vision applications such as surveillance, security, etc. require robust detection of image features. Images captured under low-light conditions (e.g. night time, indoor and underexposure), however, suffer from poor lightness and severely distorted color and thus exhibit very little scene information. Therefore, it is imperative to correct for lightness, contrast and color fidelity in order to provide a clearer view of the scene and make vision systems more reliable [2]. Images formed at low-light levels are corrupted by the noise associated with the discrete nature of light. This noise is labeled as Poisson noise, since the emission of photons is governed by a Poisson random process. The noise is clearly signal-dependent; the variance of the Poisson probability density is equal to its mean. Examples of image signals corrupted by Poisson noise occur in scintillation camera imaging, medical imaging, astronomical imaging, and low-light-level television systems. Restoration of images degraded by signal-dependent noise has been extensively studied [3].

A digital imaging system consists of an optical system followed by a photo detector and associated electrical filters. The photo detector converts the incident optical intensity to a detector current, or photons to electrons. During the process, the true signals are contaminated by many different sources of noise. In fact, the true signal itself has fluctuations in time due to the discrete nature of photons; the arrival of photons is not a steady stream and obeys the Poisson law. It implies that no matter how accurately a computer vision experiment is performed, temporal fluctuation in intensity exists. The fluctuation becomes significant especially in low-light conditions where the number of incoming photons is limited, i.e., photon-limited conditions. Important low-light vision applications include night vision, medical imaging, underwater imaging, microscopic imaging and astronomical imaging. Even in daily situations, Poisson noise often becomes significant in high-speed imaging. In these situations, uncertainty in observations increases significantly due to Poisson noise, particular operations under these conditions [4].

Many researchers have been study; the noise in the images under low lighting conditions, and some of these studies are as follows:

Salema S. Salman (2009) studied the effect of different lighting operations in type and intensity on test images using different light sources (tungsten and fluorescent lamps) and studied the homogeneity distribution of light intensity for the line partitioned from the middle of white test image width and height and focused on the contrast ratio as a function for light intensity using a test image with one half white and the other half black [5].

W.S. Malpica, A.C. Bovik (2009): they suggested full Image Quality Assessment using the structural similarity index, this method requires two images (optimal and original images) then evaluate the three different measuring values; the luminance, contrast, and structure comparison is made [6].
H. Gati’ Dway(2011): He suggested a new criterion to determine the quality of color images based on changing in lightness and contrast called Quality Factor (QF), then analysis the images using several methods of image quality assessments; like, the mean of locally (µ and σ) model, CM, EFD, SSIM and QF [7]. Diana C. Gil elt. (2011): They introduced contrast enhancement methods and Image quality is evaluated by means of objective metrics such as intensity contrast and brightness error, and by subjective assessment, execution time is also measured. They found the technique based on histogram modification presents a better trade-off considering both aspects [8].

Anwar H.M. Al-Saleh (2012) studied the effect of the light distribution on the quality of captured images under different amount of lightness conditions then enhancing these images using an adaptive histogram equalization method and Lee’s method using color YIQ space. The results were analyzed and compute the quality of the enhancement images by using various statistical criteria based on the mean and standard deviation. Where the Adaptive histogram equalization technique gives a good quality for the enhanced images for different lightness conditions [9].

Muna Abdul Hussain Radhi1 (2014): studied the effect of the light distribution on the quality of captured images under different lightness conditions then enhancing the captured images using Histogram equalization method using YIQ color space. [10]. Devanand Bhonsle.elt (2015): Introduces a technique of bivariate threshold based dual tree complex Wavelet transform (DTCWT) to remove additive and multiplicative both the noise signals. Since both the noise is different in nature hence it is difficult to remove both types of noise by using single filter. Therefore two different filters are required to denoise medical images which are corrupted by either of the noises simultaneously [11].

2. LIGHT AND CAPTURE IMAGE QUALITY

Light is just one portion of the various electromagnetic waves flying through space. These waves have a frequency and a length, the values which are distinguishing light from other forms of energy on the electromagnetic spectrum. Light is emitted from a body due to radiation, Electric Discharge, Electro luminescence and Photoluminescence [12]. Most of images cannot exist without light. To produce an image, the scene must be illuminated with one or more light sources. In this section can be focus on interaction of light with surface and some artificial light source. Moreover can be determining general factors that the effect on the light equality assessment. Lighting quality depends on several factors, it depends largely on people’s expectations and past experiences of electric lighting. The lighting quality cannot be expressed simply in terms of photometric measures nor can there be a single universally applicable recipe for good quality lighting[13].

3. IMAGE NOISE

The noise in the images is generally defined as unwanted information leading to the distortion of the image and weakens their clarity. Also the capture process or record digital image (Digital Image Acquisition) which is converted visual image into an electrical signal is subject to an ongoing process of division and numbering usually later on lead to the emergence of noise. There are also fluctuations or oscillations occur because of natural phenomena in the vicinity of imaging system or imaging system itself adds random values to the real values for each element of the image [14]. Usually resulting images for different imaging systems accompanied by distortions and noise in various cultural norms depends on the type of imaging system and the nature of the waves that are used, and the surrounding circumstances during shooting or playback, for example, work electrician near the TV engine causes deformation disorder on the display and this is the result of interference quotient between referring the electric motor and the TV signals, therefore, the engine signals described as noise or unwanted information leading to tarnish the image of television signals [15].

3.1 Mathematical Noise Models

The existence of noise in the pictures makes them distorted, which makes the analysis of these images difficult process, and therefore the study of noise helps a lot to know the impact and determine the best techniques to remove them possibly at the lowest loss. The noise types can be classified mathematically in to three main groups: [16]

3.1.1 Additive Noise

The additive noise is the simplest noise types that possibly deform the digital images, and be written in terms of observed image I(x, y) of the real image R(x, y) additive signal independent noise N(x, y). (In other words caused by external factors that doesn’t relate to the original signal) and it is characterized by a zero mean and variability can take specific values adopted by imaging system and the nature of the target or scene. Mathematically Additive signal independent equation given by [17]:

\[ I(x, y) = R(x, y) + N(x, y) \]  \( \text{... ... (1)} \)

This type of noise is characterized as: a white noise and Statistical approximations for the distribution of additive noise usually approaching to Gaussian distribution or uniform Distribution.
3.1.2 Multiplicative Noise

Multiplicative noise can be considered a noise depend on the signal noise (Signal dependent noise), which means that the bright areas of the image are with a high noise, and whenever the intensity of light was less the noise was less. This means that the relationship between the amount of noise and the rate of the light intensity are positively related and this noise characterized as:[18].A color noise and often approaching from Chi -square distribution for coherent noise and Poisson distribution for photonic noise. The resulting observed image is a real image multiplied by the multiplicative noise parameter as shown in the following mathematical formula [19]:

\[ f(x, y) = R(x, y) F(x, y) \]  

Also, can be write eq. (1) to represent multiplicative noise, or signal dependent noise as follow [19]:

\[ I(x, y) = R(x, y) + N(R(x, y)) \]  

The signal dependent noise can be represent by [19]

\[ I(x, y) = R(x, y) + n(x, y).R(x, y) \]  

\[ F(x, y) = 1 + n(x, y) \]  

Where: F (x, y) represents a fading multiplicative random signal that possible to be type of coherent noise or Poisson noise. It is signal independent parameter of mean equal unity (F =1).

3.1.3 Impulse noise

Impulse noise has the property of either leaving a pixel unmodified with probability 1- P, or replacing it totally with probability P. This is shown in eq. (7)

\[ I(x,y) = \begin{cases} n(x,y) & \text{with probability } P \\ R(x,y) & \text{with probability } 1-P \end{cases} \]  

Restricting n(x, y) to producing only the extreme intensities (0 or 255) results in salt- pepper noise. The source of impulse noise is usually the result of an error in transmission or an atmospheric or Man-mad disturbance [20].

4. MODELLING AND LEAST SQUARES FITTING

The Method of Least Squares is a procedure to determine the best fit curve to data; the proof uses simple calculus and linear algebra. The basic problem is to find the best fit function [21]. The oldest (and still most frequent) use of ordinary least squares (OLS) was linear regression, which corresponds to the problem of finding a line (or curve) that best fits a set of data. In the standard formulation, a set of N pairs of observations (x, y) is used to find a function giving the value of the dependent variable (Yi) from the values of an independent variable (x). With one variable and approximated function f(x). The prediction is given by the following eq. [21]:

\[ Y_i = f(x_i) \]  

This equation involves some parameters which be obtained. Where obtain using least square method by minimize the sum of the squares (hence the name least squares) between the measurements and the model f(x,y) (i.e., the predicted values). This amounts to minimizing the expression [22].

\[ S = \sum_{i=1}^{n} (f(x_i) - y_i)^2 = \sum_{i=1}^{n} (f(x_i) - y_i)^2 \]  

\[ f(x_i) = \text{approximate function} \]

Can be optimizing eq. (8b) to get least square function parameters value to estimate the best function f(x_i).

5. EXPERIMENTAL WORK

In this study it has been captured several images for the test image that contain two parts (white and black) shown in the Fig. (1) and placed at a distance (one meter) in front of the two cameras (Sony and Samsung) as shown Fig (2) and the light source put behind the cameras, a light sources are composed of three Fluorescent lamps as shown Fig (3). Lighting are controlled through change lamps according to (lamps power using different lamps sizes). The incident light to the target image measured by using Lux meter device as shown Fig (4), then the images were captured in different lighting values (0 to7 Lux) respectively.
6. THE DEVICES USED IN THIS WORK

The components adopted in this study are:

a) A digital Sony camera (Cyber-Shot DSC-W620/sc) and Samsung camera (Cyber-Shot DSC-H70) shown in Fig (2), with technical specifications tabulated in Table (1).

Table 1: Characteristics of Samsung camera and Sony camera.

<table>
<thead>
<tr>
<th>Technical Specification</th>
<th>Samsung Camera</th>
<th>Sony Camera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical Sensor Resolution</td>
<td>14.2 Megapixels</td>
<td>14.1 Megapixels</td>
</tr>
<tr>
<td>Optical Zoom</td>
<td>5x</td>
<td>5x</td>
</tr>
<tr>
<td>Digital Zoom</td>
<td>1 – 3x</td>
<td>1 – 3x</td>
</tr>
<tr>
<td>LCD Screen Size</td>
<td>2.7 inch</td>
<td>2.7 inch</td>
</tr>
<tr>
<td>Sensor Type</td>
<td>CCD</td>
<td>CCD</td>
</tr>
<tr>
<td>Inbuilt Memory:</td>
<td>37 MB</td>
<td>37 MB</td>
</tr>
<tr>
<td>Focal Length</td>
<td>4.9 – 24.5 mm (35 mm Equivalent to 27 – 135 mm)</td>
<td>5 – 25 mm (35 mm Equivalent to 28 – 135 mm)</td>
</tr>
<tr>
<td>Battery Type</td>
<td>BP70A Li-ion Rechargeable Battery</td>
<td>NP-BN1 Remember a Spare Battery</td>
</tr>
</tbody>
</table>

b) Light source: Fluorescent lumps characteristics as follows
- Voltage (220-240) Volt.
- Frequency (50) Hz.
- Color Temperature (5500) K.
- Power according to size (9, 18, 40 and 60) Watt.

The used fluorescent lumps shown in the Fig (3).
c) Luxmeter LX1010B
There are many properties of the lux meter as shown in Fig (4) can be described as follows
- Ranges: 0 - 50,000 Lux.
- High Accuracy and rapid response.
- Auto Zeroing; Over-range indication.
- LCD Display; Data Hold; Low battery alert.
- 12 Months Warranty.

Figure 4 digital luxmeter model (LX1010B) china

7. THE PROCESSING STEPS AND ALGORITHMS
The block diagram shown in Fig (5) the suggested processing steps for determine the model equations for additive signal dependent noise in capture image under low lightness conditions. Where in this study, the work was divided into several steps

The work focused on the analysis of digital images that captured low lightness, were used two cameras (Sony and Samsung) to capture images of one test image of two targets (black and white) as shown in Fig (6), for the purpose of controlling the intensity of lightness have been replaced fluorescent aforementioned lamps. Where light intensity was measured using the Lux meter, then the captured image are divided into targets (black and white) each target used for two camera types (Samsung and Sony) as shown in the Fig (7) and (8) respectively.

Then compute some of statistical parameters such as mean (µ), and additive signal depended noise for each frame image by using algorithm built in MATLAB program version(7.14) R2012a, according to algorithm(1).

Algorithm (1) Shown the steps of determine additive signal dependent noise distribution

| Input: | The images captured under lowlight conditions I(x, y). |
| Output: | Compute Probability Density function for the additive signal dependent noise P(N). |
| Start algorithm | |
| 1- Load image I(x, y). | |
| 2- Compute : | |
| i) Mean of the image : | \[ \mu = \frac{1}{MN} \sum_{x=1}^{MN} \sum_{y=1}^{MN} I(x, y) \] |
| ii) Additive noise using : | \[ N = I - \mu \] |
| 3- Compute Probability Density function for the additive signal dependent noise P(N). (i.e compute P(N)). | |
| 4- Save the output Data P (N). | |
| 5- End algorithm. | |
Finally, Using Table Curve fitting program software (TC) “2D version 5.01, 2007” to Estimate the Probability Density function of the additive signal dependent noise \( P(N) \). Then determine a mathematical model for fitting functions to find the relationship between \( N \) and \( P(N) \). After that have be perform verification between real values and theoretical values compute from estimated mathematical model function for the two camera types for different lightness values.

8. The Results and Discussions

To estimate the best models for (black and White) image target from two camera types (Samsung and Sony) shown Fig (9) for black image target and Fig (10) for white image target, It is represents the relationship between distribution probability of additive signal dependent noise \( P(N) \) as a function of additive signal dependent noise \( N \) for different lighting, values the estimate best model for the noise distribution is a Gaussian function given by:

\[
P(N) = e^{a_1 + b_1 N^2} \quad \ldots \ldots \quad (9)
\]

- \((a_i\text{ and }b_i)\): parameters of the fitting equation for the \( P(N) \).

From the Fig (9 and 10) the \((y)\) axis represents the distribution probability of additive signal dependent noise \( p(N) \), and \((x)\) axis represent additive signal dependent noise values \( N \). Fitting process using image at lightness \((L=0, 1, 2, 3, 5, 6, 7\text{ Lux})\) and ignore \((L=4\text{ Lux})\) from calculation the model by the tables 2 and table 3 for (Black and White) image targets respectively.

![Image](image1.png)

![Image](image2.png)

**Figure 6** Shows The captured images in different lightness values of two types camera (a) Samsung (b) Sony camera.

![Image](image3.png)

![Image](image4.png)

**Figure 7** Shows The black target from the captured images in different lightness values for the two camera types (a) Samsung (b) Sony.
Figure 8 Shows The white target from the captured images in different lightness values for the two camera types (a) Samsung (b) Sony.

Figure 9 Shows The Relationship between probability and additive signal dependent noise (N) for black target for two camera types (a) Samsung (b) Sony at different lightness values.
Table 2: The ($a_2$ and $b_3$) parameters of the fitting eq. for the $P(N)$ for black target for two camera types (Samsung and Sony) at different lightness values

<table>
<thead>
<tr>
<th>L(Lux)</th>
<th>a-parameter</th>
<th>b-parameter</th>
<th>r²-parameter (correlation)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Samsung</td>
<td>Sony</td>
<td>Samsung</td>
</tr>
<tr>
<td>0</td>
<td>-1.363</td>
<td>-1.701</td>
<td>-0.171</td>
</tr>
<tr>
<td>1</td>
<td>-1.388</td>
<td>-1.750</td>
<td>-0.175</td>
</tr>
<tr>
<td>2</td>
<td>-1.464</td>
<td>-1.814</td>
<td>-0.100</td>
</tr>
<tr>
<td>3</td>
<td>-1.453</td>
<td>-1.88964</td>
<td>-0.152</td>
</tr>
<tr>
<td>4</td>
<td>-1.491</td>
<td>-1.88962</td>
<td>-0.143</td>
</tr>
<tr>
<td>5</td>
<td>-1.532</td>
<td>-1.897</td>
<td>-0.101</td>
</tr>
<tr>
<td>6</td>
<td>-1.549</td>
<td>-1.918</td>
<td>-0.124</td>
</tr>
<tr>
<td>7</td>
<td>-1.586</td>
<td>-1.958</td>
<td>-0.120</td>
</tr>
</tbody>
</table>

Figure 10 Shows The Relationship between probability and additive signal dependent noise (n) for white target for two camera types ((a) Samsung (b) Sony) at different lightness values.
Then using Table curve to draw the relationship between \((a_i\) and \(b_i\)) parameters as a function of \((L)\) see Fig (11) for black image target for Samsung and Sony cameras respectively, the Fig mentioned above notice that the parameter \((a_i)\) is high matching with real data according to the information matching \((r^2)\), the \(r^2\) represent parameter (correlation) while the parameter \(b_i\) is (less information matching) as in table (4). Fig (12) represent the relationship between \((a_i\) and \(b_i\)) parameters as a function of \((L)\) for white image target for Samsung and Sony cameras respectively and notice that the \((a_i\) and \(b_i\)) parameters are high matching with real data according to the information matching \((r^2)\) where the parameter \(a_i\) is decreasing with increase \((L)\), while the parameter \(b_i\) is increase with increase \((L)\). The estimated function for \(a_i\) parameter for two cameras (Samsung and Sony) for black image target given by:

\[
a_i = a_{i1} + b_{i1}L + c_{i1}L^2 \quad \ldots \ldots \quad (10)
\]

While for \(b_i\) parameter for two cameras (Samsung and Sony) for black image target by:

\[
b_i = a_{i2} + b_{i2}\sqrt{L} + c_{i2}L + d_{i2}L^{1.5} + e_{i2}L^2 + f_{i2}L^{2.5} \quad \ldots \ldots \quad (11)
\]

<table>
<thead>
<tr>
<th>L(Lux)</th>
<th>Samsung</th>
<th>Sony</th>
<th>Samsung</th>
<th>Sony</th>
<th>Samsung</th>
<th>Sony</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-1.367</td>
<td>-1.558</td>
<td>-0.166</td>
<td>-0.103</td>
<td>0.935</td>
<td>0.912</td>
</tr>
<tr>
<td>1</td>
<td>-2.099</td>
<td>-2.275</td>
<td>-0.045</td>
<td>-0.0313</td>
<td>0.985</td>
<td>0.972</td>
</tr>
<tr>
<td>2</td>
<td>-2.383</td>
<td>-2.349</td>
<td>-0.026</td>
<td>-0.025</td>
<td>0.996</td>
<td>0.954</td>
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<tr>
<td>3</td>
<td>-2.648</td>
<td>-2.533</td>
<td>-0.015</td>
<td>-0.017</td>
<td>0.999</td>
<td>0.968</td>
</tr>
<tr>
<td>4</td>
<td>-2.775</td>
<td>-2.510</td>
<td>0.011</td>
<td>-0.025</td>
<td>0.996</td>
<td>0.993</td>
</tr>
<tr>
<td>5</td>
<td>-2.819</td>
<td>-2.474</td>
<td>0.010</td>
<td>-0.021</td>
<td>0.994</td>
<td>0.987</td>
</tr>
<tr>
<td>6</td>
<td>-2.858</td>
<td>-2.476</td>
<td>0.009</td>
<td>-0.021</td>
<td>0.989</td>
<td>0.984</td>
</tr>
<tr>
<td>7</td>
<td>-2.927</td>
<td>-2.468</td>
<td>0.008</td>
<td>-0.022</td>
<td>0.977</td>
<td>0.993</td>
</tr>
</tbody>
</table>

Table 3: The \((a_i\) and \(b_i\)) parameters of the fitting eq. for the P \((N)\) for white target for two camera types (Samsung and Sony) at different lightness values.

<table>
<thead>
<tr>
<th>a-parameter</th>
<th>b-parameter</th>
<th>r²-parameter ( correlation)</th>
</tr>
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<tbody>
<tr>
<td>Samsung</td>
<td>Sony</td>
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<td>-2.533</td>
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<tr>
<td>4</td>
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<td>6</td>
<td>-2.858</td>
<td>-2.476</td>
</tr>
<tr>
<td>7</td>
<td>-2.927</td>
<td>-2.468</td>
</tr>
</tbody>
</table>

For black image target from eq. (10), eq. (11) and Table (4) for two types of Cameras (Samsung and Sony) can be getting the following model:

\[
P(N) = e^{(a_{11} + b_{11}L + c_{11}L^2)} + (a_{12} + b_{12}\sqrt{L} + c_{12}L + d_{12}L^{1.5} + e_{12}L^2 + f_{12}L^{2.5})N^2 \quad \ldots \ldots \quad (12)
\]

Eq. (12) represents a mathematical model between noise distributions P \((N)\) as a function of lightness \((L)\). Here if anyone knew any two variables of the three variables \((P(N), N,\) and \(L)\) can be easily conclude to the third variable. From eq. (12) can be compute the value of distribution probability for the additive signal dependent noise P \((N)\) at the lightness value \((L = 4\) Lux), To compare with the actual values that have been get them using the algorithm (1) for the same lighting value and compared the theoretical and practical data for two cameras shown Fig. (13).
Figure 11 Shows The Relationship between (a and b) parameters as function of lightness (L) in Black image target for two camera types (a) Samsung (b) Sony camera.

Figure 12 Shows The Relationship between (a and b) parameters as function of lightness (L) in White image target for two camera types (a) Samsung (b) Sony camera.

Figure 13 shows Comparing the theoretical and practical data curve for the two Camera type for Black image Target when (L=4 Lux).

While, the estimated function for a- parameter for two cameras (Samsung and Sony) for white image target as:

\[ a_i = a_{i1} + b_{i1}L + c_{i1}\sqrt{L} \ldots \ldots \ldots \ldots (13) \]
While for \( b \) - parameter for two cameras (Samsung and Sony) as:

\[
b_i = a_{i2} + b_{i2}L + c_{i2}L^{2.5} + d_{i2}\sqrt{L}
\]

\[\ldots \ldots \ldots (14)\]

For white image target from eq. (13), eq. (14) and Table (5) for two types of Cameras (Samsung and Sony) can be get:

\[
P(N) = e^{(a_{i1}+b_{i1}L+c_{i1}\sqrt{L})+(a_{i2}+b_{i2}L+c_{i2}L^{2.5}+d_{i2}\sqrt{L})} \cdot N^2
\]

\[\ldots \ldots \ldots (15)\]

Eq.(15) represents a mathematical model between noise distribution \( P(N) \) as a function of lightness \( L \) and here if anyone knew any two variables of the three variables \( (P(N), N, and \ \ L) \) can be easily infer to the third variable. From eq. (15) can be compute the distribution probability of additive signal dependent noise \( P(N) \) at the light \( L = 4 \ \text{Lux} \), to compare with the actual values that have been get them using the algorithm (1) for the same lighting value and compared the theoretical and practical data for two cameras see in Fig. (14).

Table 5: The parameters values for the eq. (13 and 14) for two Camera Types (Samsung and Sony) for White image target.

<table>
<thead>
<tr>
<th>Cameras</th>
<th>( a_{i1} )</th>
<th>( b_{i1} )</th>
<th>( c_{i1} )</th>
<th>( r^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung</td>
<td>-1.348</td>
<td>0.124</td>
<td>-0.9</td>
<td>0.993</td>
</tr>
<tr>
<td>Sony</td>
<td>-1.562</td>
<td>0.212</td>
<td>-0.897</td>
<td>0.988</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>White Target</th>
<th>( a_{i2} )</th>
<th>( b_{i2} )</th>
<th>( c_{i2} )</th>
<th>( d_{i2} )</th>
<th>( r^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Samsung</td>
<td>-0.166</td>
<td>-0.049</td>
<td>0.0004</td>
<td>0.168</td>
<td>0.999</td>
</tr>
<tr>
<td>Sony</td>
<td>-0.102</td>
<td>-0.033</td>
<td>0.0003</td>
<td>0.102</td>
<td>0.996</td>
</tr>
</tbody>
</table>

For white image target from eq. (13), eq. (14) and Table (5) for two types of Cameras (Samsung and Sony) can be get:

\[P(N) = e^{(a_{i1}+b_{i1}L+c_{i1}\sqrt{L})+(a_{i2}+b_{i2}L+c_{i2}L^{2.5}+d_{i2}\sqrt{L})} \cdot N^2\]

\[\ldots \ldots \ldots (15)\]

**Figure 14** shows Comparing the theoretical and practical data curve for the two Camera types for White image target when \( L=4 \ \text{Lux} \)

9. **CONCLUSION**

It has been get efficient Gaussian distribution mathematical model for the distribution probability of additive signal dependent noise \( P(N) \) for the Samsung and Sony camera and for both image targets Black and White.

1. Estimate the best mathematical model for the two camera types (Samsung and Sony) and for Black image target for additive signal dependent noise distribution as a function of lightness this model given by:

\[P(N) = e^{(a_{i1}+b_{i1}L+c_{i1}\sqrt{L})+(a_{i2}+b_{i2}L+c_{i2}L^{2.5}+d_{i2}\sqrt{L})} \cdot N^2\]

2. Estimate the best mathematical model for the two camera types (Samsung and Sony) and for White image target additive signal dependent noise distribution as a function of lightness this model given by:

\[P(N) = e^{(a_{i1}+b_{i1}L+c_{i1}\sqrt{L})+(a_{i2}+b_{i2}L+c_{i2}L^{2.5}+d_{i2}\sqrt{L})} \cdot N^2\]

3. The parameter of \( a_i \) is high matching with real data according to the information matching \( (r^2) \) while the parameter of \( b_i \) is less information matching \( (r^2) \) for the two Camera types for Black image target.

4. The \( (a_i \text{ and } b_i) \) parameters are high matching with real data to the information matching \( (r^2) \) where the parameter \( a_i \) is decreasing with increase \( L \), while the parameter \( b_i \) is increasing with increase \( L \) for the two Camera types.
The obtained results from the estimated models are excellent and very close to the practical value.

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